R E P O R T   R E S U M E S

ED 011 509 SE 000 738

THE DESIGN OF INSTRUCTION.

BY- GLASER, ROBERT

PITTSBURGH UNIV., PA., LEARNING RES. AND DEV. CTR.

REPORT NUMBER REPRINT-5 PUB DATE 66

NATIONAL SOCIETY FOR THE STUDY OF EDUC., CHICAGO

EDRS PRICE MF-$0.09 HC-$1.28 32P.

DESCRIPTORS- *EDUCATIONAL OBJECTIVES, *EVALUATION, *LEARNING THEORIES, *TEACHING METHODS, CONCEPT FORMATION, INSTRUCTION, MOTIVATION, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, CHICAGO, RESEARCH AND DEVELOPMENT CENTER

THE THEORY AND THE RESEARCH RELEVANT TO INSTRUCTIONAL DESIGN ARE DISCUSSED IN THIS PAPER, A CHAPTER FROM THE 65TH YEARBOOK OF THE NATIONAL SOCIETY FOR THE STUDY OF EDUCATION, PART II. GENERALIZATION, CONCEPT FORMATION, AND "PROCESS" OBJECTIVES ARE DISCUSSED IN A SECTION DEVOTED TO THE ANALYSIS OF SUBJECT-MATTER OBJECTIVES OF INSTRUCTION. THE IMPORTANCE OF ADEQUATELY ASSESSING PREINSTRUCTIONAL STUDENT BEHAVIOR IS TREATED. KINDS OF BEHAVIORAL OPERATIONS IN LEARNING AS WELL AS SOME CONDITIONS THAT INFLUENCE LEARNING ARE DISCUSSED. PROCEDURES FOR EVALUATING ACHIEVEMENT ARE ANALYZED. THE AUTHOR CONCLUDED THAT MODERN EXPERIMENTAL PSYCHOLOGY HAS RARELY BEEN A SIGNIFICANT INFLUENCE IN THE DEVELOPMENT OF TEACHING MATERIALS AND TEACHING PROCEDURES. IN ADDITION, HE HYPOTHESIZED THAT THE EDUCATIVE PROCESS AND INSTRUCTIONAL PROCEDURES WILL BE INFLUENCED BY RESEARCH AND MARKED CHANGES WILL OCCUR IN SCHOOL OPERATIONS. CHANGES THAT ARE LIKELY TO OCCUR ARE THE ROLE OF THE TEACHER, INDIVIDUALIZING INSTRUCTION, CAREFUL EXAMINATION OF INSTRUCTIONAL MATERIALS FOR EDUCATION EFFECTIVENESS, AND IMPROVEMENT IN EVALUATION INSTRUMENTS AND TECHNIQUES. THIS ARTICLE IS PUBLISHED IN THE SIXTY-FIFTH YEARBOOK OF THE NATIONAL SOCIETY FOR THE STUDY OF EDUCATION, PART II. (RS)

THE DESIGN OF INSTRUCTION

ROBERT GLASER

Professor of Education and Psychology
Director, Learning Research and Development Center
University of Pittsburgh
Pittsburgh, Pennsylvania

Offprint from the
Sixty-fifth Yearbook of the National Society
for the Study of Education, Part II

THE CHANGING AMERICAN SCHOOL
1966

Note: This offprint of Chapter IX (pp. 215-42) of the Sixty-fifth Yearbook, Part II, is made by permission of the Society for private distribution by the Author. Copies of the entire yearbook (320 pp.) from which this offprint is made may be secured for $5.00, postpaid in cloth binding, from The University of Chicago Press

THE NATIONAL SOCIETY FOR THE
STUDY OF EDUCATION

5835 Kimbark Avenue
CHICAGO, ILLINOIS 60637

CHAPTER IX

The Design of Instruction[1]

ROBERT GLASER

The use of modern science in the interest of society has become an important obligation of our times. This is true no less in education than it is in medicine and engineering. As increasing knowledge is accumulated in psychology and the behavioral sciences in general, a foundation is provided for a growing scientific and technological base for instructional practice. The translation of scientific knowledge into practice requires extensive applied research and technological development. However, at this time, an entity to carry out the function of instructional design and development hardly exists. If a person (or organization) were to carry out such a function, how would he begin to work, and in what sort of conceptual framework would he perform his job? This chapter speculates about and discusses such a framework and describes some of the concepts that an "instructional designer" might use in thinking about his work. The tasks he must perform involve the interplay between theory, research, and application. This chapter describes, not application as such, but aspects of the necessary research and development which can eventually lead to innovation and redesign in instructional practice. Evidences of such innovation and redesign are beginning to mark the changing American school.

It is apparent that forces are at work which are encouraging the increasing growth of the scientific underpinnings of educational practice and the development of "engineering" enterprises that back up the teaching profession. In many ways these enterprises are like

1. The preparation of this paper was accomplished under the auspices of the Learning Research and Development Center, University of Pittsburgh, with support from the Cooperative Research Program of the United States Office of Education.

the "engineering" organizations, such as pharmaceutical manufacturers and industrial research laboratories, that provide materials for use by the medical and engineering professions. The forces encouraging research and development basic to instructional practice are the following: (*a*) the increasing recognition among psychologists that their work has been too remote from the many problems of classroom learning, this recognition being spurred on, for example, by the basic research that had led to programed learning in the form of programed texts and teaching machines; (*b*) the increasing sophistication of the teaching profession which is forcing the behavioral scientist to provide it with knowledge relevant to the educational process; and (*c*) the increasing national sponsorship of centers and laboratories dedicated to mutually supporting relationships between behavioral science and educational practice.

Out of these trends will grow the "instructional designer" mentioned above, and the remainder of this chapter suggests some theory and research which can influence his activities. If the instructional designer, working in a research and development setting, did exist, then it can be assumed that he would operate in the following manner: First, he would analyze the subject-matter domain under consideration—reading, mathematics, or other. He would think of a domain in terms of the performance competencies which comprise it. He would analyze representative instances of subject-matter competence according to the stimulus characteristics of the content involved and the properties of the responses the student makes to the content. (Response is used here to mean broad activity ranging from memorizing to problem-solving.) He would further analyze the structural characteristics of the domain, perhaps according to its conceptual hierarchies and operating rules. Second, this instructional designer would turn his attention to the characteristics of the students that are to be taught. He would determine the extent to which the students already have acquired some of the things to be learned, the extent to which they have certain content prerequisites, the extent to which their antecedent learnings might facilitate or interfere with the new learning, and the extent to which the students have certain aptitude-like prerequisites consisting of necessary sensory discriminations and motor skills.

These first two steps provide information to the educational de-

signer about the target performance to be obtained and the existing preinstructional behavior of the learner. The designer must then proceed to get from one state to the other. This sets up his third task. This task consists of helping the student go from the preinstructional behavioral state to a state of subject-matter competence. This requires the construction of teaching procedures and materials to be employed in the educational process. As part of this process, he must take account of motivational effects and the ability of humans to generalize and extrapolate; this is accomplished by providing conditions which will result in the maintenance and extension of the competence being taught. Finally, the educational designer must make provision for assessing and evaluating the nature of the competence and kind of knowledge achieved by the learner in relation to some performance criteria that have been established.

To many present-day educational practitioners this description of the process of instructional design may sound harshly technological, and indeed, perhaps some elegance has been lost in analysis. But, presumably, once basic techniques are constructed, the teacher can use the tools of his profession with understanding, artistry, and sensitivity. The design components that have just been described are (*a*) analyzing the characteristics of subject-matter competence, (*b*) diagnosing preinstructional behavior, (*c*) carrying out the instructional process, and (*d*) measuring learning outcomes. This chapter comments further about each of these.

Analyzing the Characteristics of Subject-Matter Competence

When the psychologist turns his attention from analysis of the behavior involved in standardized, arbitrary tasks used in the laboratory to the identification of the processes involved in learning the nonarbitrary behavior generally taught in our culture, he runs head on into the problem of the analysis of subject-matter tasks. The significance of this problem was high-lighted by psychologists when they turned their attention to practical training, as they did in the Air Force program under the direction of Arthur W. Melton. The concern with task analysis is a reaction to the fact that, while the laboratory investigator decides upon and constructs an experimental task pertinent to his particular purposes, he is not in a position to do this in the ongoing educational setting. In the laboratory, by

preselecting his task to fit a problem, he has in a sense analyzed its stimulus and response characteristics. However, when working with nonarbitrary behavior, he is faced with the problem of identifying the properties of the behavior involved so that he can proceed to operate in his usual way. As a behavioral scientist he is accustomed to working with specified behavior, and he needs to do so in the instructional situation. The transition from the laboratory to application frequently requires this additional consideration. The recent writings and explorations of Bruner,[2] for example, continuously emphasize a concern with subject-matter structure, and this most likely develops out of his concern with real-life subject matter.

The significance of subject-matter analysis is emphasized when a psychologist,[3] involving himself in the learning of a second language, discovers to his good fortune that much time already has been devoted to the systematic specification of the terminal behaviors of language instruction. By contrast, working in the field of English, another psychologist[4] indicates that a major problem is the need for better specification of the behavior to be taught by English teachers. It is interesting to point out that, in English, the prescriptive nature of traditional grammar has "apparently settled in prescriptive methods of instruction."[5] In this case, the characteristics of the subject matter affected instructional techniques, and detailed analysis of subject-matter properties, in turn, probably will demand advances in instructional procedure. Some illustrative influences of

2. Jerome S. Bruner, *The Process of Education* (Cambridge, Massachusetts: Harvard University Press, 1960); and "Some Theorems on Instruction Illustrated with Reference to Mathematics," in *Theories of Learning and Instruction* (The Sixty-third Yearbook of the National Society for the Study of Education, Part I. Edited by E. R. Hilgard. Chicago: University of Chicago Press, 1964).

3. H. L. Lane, "Programed Learning of a Second Language," in *Teaching Machines and Programed Learning, II: Data and Directions*. Edited by Robert Glaser. Washington: National Education Association, 1965.

4. Susan M. Markle, "Programed Instruction in English," in *Teaching Machines and Programed Learning, II: Data and Directions, op. cit.*

5. *Ibid.*

subject-matter characteristics upon the investigation of learning and instruction are suggested below.

First is the distinction between component repertoires and content repertoires. Content repertoire refers to a subject-matter oriented analysis. Component repertoire refers to a behavioral analysis. A subject-matter expert can generally divide his subject into subtopics, primarily on the basis of content interrelationships and subject-matter logic and arrangement. By contrast, a psychologist considers content analysis less and behavior analysis more. Particularly, he looks for the kinds of stimulus-response situations involved. The concern of psychologists with taxonomies [6] reflects initial attempts to develop schemes for describing and analyzing component repertoires.

From the point of view of instruction, the practical requirement for component-repertoire analysis is to identify the kind of behavior involved so that the learner can be provided with instructional procedures and environmental conditions which best facilitate the learning of that kind of behavior. The underlying assumption is that the learning of various kinds of component repertoires requires different kinds of teaching procedures, and a research task is to identify the learning processes and appropriate instructional procedures associated with different component repertoires. This kind of thinking underlies Gagné's [7] analysis of instructional objectives for the design of instruction when he lists response differentiation, association, multiple discrimination, behavior chains, class concepts, principles, and strategies as categories of behavior and attempts to suggest learning conditions relevant to each category.

Designing optimal instruction may be a matter of choosing tactics appropriate to categories of behavior implied by the noncontent

6. Arthur W. Melton, "The Science of Learning and the Technology of Educational Methods," *Harvard Educational Review*, XXIX (Spring, 1959), 96-106. (Also in *Teaching Machines and Programed Learning*. Edited by A. A. Lumsdaine and Robert Glaser. Washington: National Education Association, 1960.)

7. Robert M. Gagné, "The Analysis of Instructional Objectives for the Design of Instruction," in *Teaching Machines and Programed Learning, II: Data and Directions, op. cit.*; and Robert M. Gagné, *The Conditions of Learning* (New York: Holt, Rinehart & Winston, 1965).

characteristics of instructional objectives.[8] In this context, such fields as linguistics and logic, devoted to analysis of organized knowledge, should become increasingly useful in providing insights into the relationship between subject-matter structure and the behavioral structure required for learning. For example, a contrastive analysis of the linguistic requirements of a student's first language and the target second language to be learned can provide details for an instructional prescription.

Second is the distinction between *product and process*. The trend toward the behavioral analysis of instructional objectives has led to the use of the term, "process" objectives. The curriculum for science in the elementary grades,[9] developed under the auspices of the American Association for the Advancement of Science, considers process objectives, such as observation, classification, prediction, and inference. The content as such, whether magnetism, sound, light or heat phenomena, or biological events, is of secondary importance in this curriculum. The learning of "processes" is more important. Also, at the higher levels of science teaching, there is increasing concern with more than "formal and descriptive knowledge" of the current body of science. Emphasis is placed on such behaviors as generating hypotheses, selecting fruitful hypotheses, testing hypotheses and deciding upon experiments, and the more generalized traits of a scientist, such as perseverance and curiosity. The trend toward the statement of so-called process objectives reflects a recognition of the importance of the component repertoire.

It should be pointed out, however, that the word "process" in process objective can be somewhat misleading. A statement of an objective refers to a behavioral state which is some performance by the student, and the performance itself, or the results of the performance, can be measured in some way. It is important to distinguish between the behavioral state and the process of attaining the behavioral state, which is carried out by an instructional sequence. Perhaps nowhere in recent years has the confusion between process

8. Thomas F. Gilbert, "Mathetics: The Technology of Education," *Journal of Mathetics*, I (January, 1962), 7-73.

9. *Science—A Process Approach*. American Association for the Advancement of Science, 1963.

and state been more rampant than in the recent emphasis on "discovery learning." In both the practical and the research work in this area, there is a confusion between two kinds of events: one event has to do with learning *by* discovery (process), that is, teaching certain objectives by a discovery method; the other event has to do with learning *to* discover (a behavioral state), or teaching for a terminal state which is manifested by the ability to make discoveries.

Third is the significance of *transfer and concept formation.* Subject-matter properties very significantly determine the dimensions along which the student must be taught to generalize and transfer his knowledge. Presumably the ability to generalize and to transfer is a function of experience with a variety of examples and different subject-matter instances. But what defines variety and what defines different instances that lead to generalizable knowledge? For some subject-matter aspects, there is little ambiguity about whether variations in the examples presented to a student are instances of a basic rule. However, as a subject matter becomes complex, definition of a range of examples may become difficult, and problems arise concerning whether training in various instances does, indeed, carry over to new situations.

Generalization is a significant component of concept formation, and the influence of the analysis of subject-matter dimensions can be made most clearly when one considers the teaching of concepts. Many psychologists would agree that the basic procedure for teaching the ability to use concepts involves teaching the student to generalize within classes and to discriminate between classes. The student must learn to make the same responses to all members falling within a class and to make different responses to members of different classes. The procedure involved can be illustrated by the simple case of teaching a child the concepts of red and blue. Discrimination and generalization trials are presented with the colors red and blue. Other properties of the objects are varied randomly so that the student learns to generalize among objects having in common no characteristic other than their color. For example: First, the child is shown successive sets of three objects, two red ones and one not red. Each time these three objects are presented the question is asked, "Which is not red?" This is repeated a number of times with only two blue objects. In this way discriminations are established

between red and not red, and blue and not blue. The child might then be presented with two objects, one red and one blue and asked "Which one is red?" or "Which one is blue?" The number of nonred and nonblue objects could then be increased so that only one out of a number of objects is red or blue. In order to carry out training for generalization, objects with a variety of characteristics would be included in the sequence of color-discrimination training —large and small objects, dark and light ones, rough and smooth ones, near and far ones, square, triangular, and irregularly-shaped ones, and so forth. This would prevent the responses "red" and "blue" from being attached to stimuli other than the appropriate ones. With the properties of the objects varied, the child would learn to generalize among objects in which the common characteristic is color. In this way the child is presented with a series of progressively graded experiences by which he acquires the concepts of redness and blueness.

This instructional process becomes complicated when the subject-matter properties to be generalized and discriminated are not clear cut or become very subtle as, for instance, in the concepts classic and neoclassic art or early Mozart and late Mozart.[10] A major problem in teaching such subtle and complex concepts is the definition of the subject-matter classes. This becomes increasingly problematical when there is disagreement among experts and where there are semantic imprecisions. Sometimes the distinction between classes is not clear to the learner because he does not have the necessary training required. At other times the difficulty lies with subject-matter imprecision.

In the three points made so far, the attempt has been to show that the analysis of behavioral objectives is an area that cannot be overlooked in research and development on learning that leads to effective instructional practice. To emphasize the point, one can resort to testimonial quotes. "So important is the principle of programing that it is often regarded as the main contribution of the teaching-machine movement, but the experimental analysis of b

10. *Vide* Francis Mechner, "Science Education and Behavioral Technology," in *Teaching Machines and Programed Learning, II: Data and Directions, op. cit.*

havior has much more to contribute to a technology of education." [11] This is from Skinner, and while he means somewhat more than only the analysis of behavioral objectives, his point is certainly related to that of the writer. In analyzing English teaching, Markle says, "In the case of critical and evaluative skills in literature, the technology of task analysis is crucial. Not the technology of designing frames." [12] Gagné, with his emphasis on sequential objectives, says, "The entire sequence of objectives . . . is considered to be the most important set of variables in the instructional process, outweighing as a critical factor more familiar variables like step size, response mode, and others." [13] Crawford, in considering the extensive experiences of the Human Resources Research Office of George Washington University in army military training, says that "perhaps the most important single contribution to the development of training through research has been the determination of methods for the formulation of objectives of instruction." [14]

Diagnosing Preinstructional Behavior

Once the objectives of subject-matter behavior have been analyzed, the instructional designer turns his attention to the characteristics of the learner who is to attain these objectives. This brings up the problems involved in diagnosing the preinstructional behavior or the entering repertoire of the learner. For measurement psychologists, this has been a primary concern. For psychologists interested in learning, preinstructional individual differences have been relegated, for the most part, to error variance in experimental design. It is increasingly obvious, however, that a psychology of learning relevant to instructional practice cannot consider individual differences as error variance. Classroom and laboratory studies are constant reminders that individual differences is one of the most im-

11. B. F. Skinner, "Reflections on a Decade of Teaching Machines," in *Teaching Machines and Programed Learning, II: Data and Directions, op. cit.*

12. Markle, *op. cit.*

13. Gagné, *op. cit.*

14. Meredith P. Crawford, "Concepts of Training," in *Psychological Principles in System Development*. Edited by Robert M. Gagné. New York: Holt, Rinehart & Winston, 1962.

portant but least accepted principles of both learning theory and subject-matter teaching.[15]

In research on programed instruction, one is uniformly impressed with the extent of variability in student learning rates.[16] Rate of learning, however, is only one relevant dimension of individual differences. It is the dimension which programed instruction has emphasized, and it is probably the easiest one to accommodate (even though its adequate recognition certainly can upset the organization of a school). There are other dimensions of individual differences of equal or greater significance which pertain to the component and content repertoires of the student, i.e., aptitude pattern, skill level, et cetera. At least four classes of preinstructional variables are determinants of the course of achievement: [17] (*a*) the extent to which the individual already has acquired the responses sought, e.g., appropriate motor skills; (*b*) the extent to which the individual has acquired the prerequisites for learning the responses to be acquired, e.g., knowing how to add before learning to multiply; (*c*) the extent to which the individual has acquired the learning-set variables consisting of antecedent learnings which facilitate or interfere with new learning under certain instructional conditions, e.g., prior experience or information in a particular area; and (*d*) the individual's ability to make the discriminations necessary to profit from instruction, e.g., aptitude in spatial perception.

In the instructional process, just as objectives define the target behaviors which are accepted as givens to be attained, so must preinstructional behavior be accepted as a given, if we do not or cannot rigorously control or delimit student behavior up to the point of entry into instruction. The array of concepts involved in the pre-

15. *Vide* Patrick Suppes, "Modern Learning Theory and the Elementary-School Curriculum," *American Educational Research Journal*, I (March, 1964), 79-93.

16. Robert Glaser, James H. Reynolds, and Margaret G. Fullick, *Programmed Instruction in the Intact Classroom.* Pittsburgh: Learning Research and Development Center of the University of Pittsburgh, 1963. (Report issued under Cooperative Research Project No. 1343.)

17. Robert M. W. Travers, *Essentials of Learning: An Overview for Students of Education.* New York: Macmillan Co., 1963.

instructional measurement and diagnoses of aptitude, readiness, and achievement must be systematized for theoretical development and for use in instructional design. For example, the long-term prediction by aptitude tests of achievement scores at the end of a course might be supplemented by measures of behavior which predict whether the individual can achieve the next immediate instructional step. "In certain of the new curricula, there are data to suggest that aptitude measures correlate much less with end-of-course achievement than they do with achievement in early units." [18]

While most of the available products in programed instruction show an appalling lack of recognition of differences in entering behavior, recent discussions of programed instruction are very much concerned with it. Markle,[19] in commenting on English teaching, points out that student variability ranges from no information to misinformation and that the majority of presently available programs in English make no provision for diagnosing and then using this diagnostic information. She says, "The English instructor . . . must begin at many points and go at many paces while covering a multitude of points. . . . The task is impossible. . . . There can be little doubt that individualized instruction is a necessity, not a luxury, in English class." Carroll,[20] discussing implications for teaching of language development in children, says, "Teachers must ponder the extent to which they can attempt to alter a system of habits which are not only highly practiced, but which also probably serve a supportive role in the child's adjustment to his non-school environment."

If the assessment of preinstructional behavior is considered to be the determination of an entering behavioral repertoire which the instructional process is designed to guide and modify, then research becomes reoriented in a number of areas. In the analysis of readiness, for example, measurement of the fact that readiness factors

18. Lee J. Cronbach, "Course Improvement through Evaluation," *Teachers College Record*, LXIV (May, 1963), 675.

19. Markle, *op. cit.*

20. John B. Carroll, "Language Development in Children," in *Psycholinguistics: A Book of Readings*. Edited by S. Saporta. New York: Holt, Rinehart & Winston, 1963.

differ with age and with individuals must be supplemented by analyses of the conditions influencing these differences and the contribution of these differences to learning.

The approach to developmental norms requires reconsideration. Prevailing norms necessarily assume prevailing learning conditions; however, new learning environments can change the norms. One approach for research and development in education is to adjust a learning environment to preinstructional behavior capabilities and then to study maturational limitations.

Research on aptitudes might be reoriented. If designing instructional environments for early ages is considered, it is conceivable that the "curriculum" will not be formal subject matters like mathematics or spelling but, rather, instruction in behaviors which look more like aptitudes. The general kind of experiment that might be considered is to treat aptitudes as instructional requirements in a sequence of educational progress. Skilful teaching of the behaviors that comprise aptitude should then enhance subsequent learning achievement.

With respect to preinstructional repertoires, the important problem is to investigate the relationships between individual differences and learning variables and, more practically, to develop techniques for the accommodation of instruction to individual differences. Work along these lines points out that the identification of pertinent entering behavior can be a complex and subtle task. Entering behavior that facilitates the next learning step is related to such difficult problems as the identification of transfer hierarchies of learning. Furthermore, the identification of the relevant differences in preinstructional behavior, when one student learns and another student does not, may be extremely difficult to accomplish. Identification in nonspecific terms, such as "inadequate aptitude level" or "poor motivation," does not provide the behavioral detail required for the design of an appropriate teaching sequence.

Carrying Out the Instructional Process

Once the content and component repertoires involved in terminal behavior objectives and subobjectives are described, and once the entering behavior of the student also is described, a precise instructional process can be implemented. For example, if a student

is learning to sound out phonemes that correspond to displayed graphemes, and he does not have the pronunciation of phonemes in his repertoire, he must first be taught this behavior. If it already has been learned, then instruction concentrates on bringing the pronunciation responses under the control of appropriate graphemes. In subject-matter learning, the instructional process can be defined as a way of arranging the student's environment to expedite learnings which comprise subject-matter competence.

At least three kinds of processes seem to be involved: (*a*) setting up new forms of student behavior, such as new speaking patterns or a new skill like handwriting; (*b*) setting up new kinds of stimulus control, for example, learning to read after having learned to speak, so that the already-learned response of making speech sounds is attached to particular visual symbols; and (*c*) maintaining the behavior of the student. This third category is less involved with behavior change and more concerned with increasing the student's likelihood to behave and, therefore, often falls under the label of motivation. Brief elaboration of these general categories follows.

Setting up new forms of behavior.—A very evident characteristic of learning which leads to subject-matter mastery is the increasing precision of the student's responses. In learning complex behavior, the student's initial performance is variable and quite crude, rarely meeting the criteria of subject-matter competence. Effective instructional procedure tolerates the student's initially crude responses and gradually takes him toward mastery. The instructional process, then, must involve the establishment of successively more rigorous criteria in the progression of learner performance. Increasing competence in new learning is accomplished by gradually contracting the permissible margin of error. For example, if precise timing and tempo were being taught to a student of music, it would be unrealistic to reward the student only on those rare occasions when he briefly maintained an accurate response. Since the performance of the beginning student will be quite variable, standards should be initially gross, and performance criteria should be changed at a rate which insures continuing progress toward mastery. Each successive range of acceptable performance should include a major portion of the range of variations already in the student's performance so that there will be frequent opportunity for

the reinforcement of success. Over the sequence of instruction, the range of observed performance will align itself with the particular range of acceptable performance defined as subject-matter competence. In the course of the instructional sequence, a sudden or inappropriate constriction in performance criteria is one environmental change which can lead to frustration or loss of interest.

Setting up new kinds of stimulus control.—Compared with the process just described, an equally if not more significant process in subject-matter learning is the stimulus control of performance. Learning a second language, for example, has stressed the importance of the transfer from an initial repertoire to a target repertoire. There is often the difficulty, say, in teaching translation, of transferring from one stimulus class to another. The oral response "flower" has to be transferred from the English word "flower" to the German word "die Blume." The restructuring of the student's entering repertoire is the pertinent instructional task, and this involves teaching new forms of response and transferring stimulus control to new subject matter. As another simplified example of the transfer of stimulus control, consider a child learning color names. The child can say the words "red" and "blue"; these responses are available for the teacher to use. The teacher must now bring the response under the control of the proper color stimuli, red and blue, so that colors can be called by their names. The transfer of stimulus control is a major process involved in teaching students to make responses to more precise subject-matter discriminations and in teaching them to use previously learned skills in response to new subject material.[21]

Maintaining behavior.—The processes just described, setting up new forms of response and new kinds of stimulus control, assume only that the behavior of an expert in a given subject matter is characterized by the facility with which this behavior is called out by particular subject-matter contexts. A further characteristic of an expert's behavior is that it is apparently self-sustaining. The expert may continue to respond for relatively long periods of time without

21. *Vide* Julian I. Taber, Robert Glaser, and Halmuth H. Schaefer, *Learning and Programed Instruction*, chap. iii. Reading, Massachusetts: Addison-Wesley Publishing Co., 1965.

apparent external support and without support from aids and references that are needed by the novice. Not only is the expert's behavior guided or controlled by the subject matter but, with increasing competence in behavior, it can be characterized as self-sustaining and highly independent of environmental supports. Research and development on the teaching and learning of such self-sustaining sequences is an important problem—a problem that is related to such behavior-maintaining situations as those which come under the labels of motivation and curiosity.

SOME CONDITIONS INFLUENCING THE INSTRUCTIONAL PROCESS

If it can be assumed that learning involves the kinds of processes just described, attention can be turned to some conditions which influence these processes. The conditions to be described are those suggested by the work of experimental psychologists and by practical attempts at instructional programing. In discussing these conditions, it is useful to introduce another term, namely "transitional behavior." If an instructional sequence is concerned with modifying student performance in order to get from entering behavior to specified terminal behavior, then transitional behavior is defined as the performance carried out by the student in the course of attaining competence in terminal behavior. Efficient learning conditions for transitional behavior may be radically different from the eventual conditions under which subject-matter competence occurs. As illustrations of conditions influencing the instructional process which can be subjected to psychological study, the following are considered: sequencing, stimulus and response factors, practice, and response contingencies.

Sequencing.—The sequencing of transitional behavior is a condition of learning which requires detailed analysis. The idea of gradual progression in programed instruction is a related notion. However, more subtle analyses are required. Scholars frequently point out that their subject is not organized as sequentially as, say, mathematics, and that instruction cannot be so carefully sequenced. Further, their subject matter requires that many considerations be handled at one time so that the student can perform in an integrated fashion. However, when one undertakes to lay out details in instructional sequences and to establish partial attainment goals, the

"all things at once" idea [22] seems to fall. Decisions need to be made, on some basis, about what is to be learned before what. The sequencing requirement cuts across many areas of interest in psychological research, certainly the area of transfer—particularly transfer from the learning of one subobjective to the entering requirements for learning the next subobjective. As Suppes [23] has pointed out, the identification of the structure of subconcepts determining the nature of transfer is a central problem in learning theory related to instruction.

Sequencing cuts across the notion of a gradual progression of difficulty in learning hierarchies. An analysis of what is meant by "difficulty" and of the variables that influence "learning difficulty" can involve an amazing number of subject-matter factors. Silberman's [24] analysis of the factors influencing sequencing in learning to read illustrates the complexity involved. The variables he lists include word frequency, letter frequency, syntactic structure, meaningfulness, redundant patterns, pronounceability, word and sentence length, word familiarity, stimulus similarity, and grapheme-phoneme correspondences.

Sequencing requirements point up at least three general problems in designing instructional sequences: (*a*) regularity of structure, (*b*) response availability, and (*c*) stimulus similarity and dissimilarity. Regularity of structure refers to the structure of concept development. The neglect of this area is very forcefully brought out when one examines most present-day methods of teaching reading. There seems to be little regularity in the development of, say, phonemic concepts, or morphemic regularities as the former are taught in the reading program by Buchanan [25] or the latter in the word analysis program by Markle.[26]

22. Markle, *op. cit.*

23. Suppes, *op. cit.*

24. Harry F. Silberman, "Reading and Related Verbal Learning," in *Teaching Machines and Programed Learning, II: Data and Directions*, *op. cit.*

25. Cynthia D. Buchanan, *Programmed Reading*. New York: McGraw-Hill Book Co., 1963.

26. Susan M. Markle, *Words: A Programed Course in Vocabulary Development*. Chicago: Science Research Associates, 1962.

Response availability refers to the notion that the responses to be learned in the course of an instructional sequence should be available at the time these responses are to be associated with or come under the control of relevant subject-matter stimuli. This is an area investigated in studies of verbal learning; for example, Underwood and Schulz [27] concluded that the pronounceability of certain verbal units was a predictor of the extent to which these units were learned in experiments on word association. Response availability would seem to be neglected in instructional design. In teaching reading, for example, there is often little relationship in language and syntactic patterns between the oral language of children and the material by which they learn to read. It has been suggested that a closer relationship between the two can profit from the facilitation involved in response availability. In everyday school practice, the experience charts by teachers take account of the availability of already strong responses. In Gagné's hierarchical charts on subobjectives,[28] an important factor is response availability, which facilitates the learning of the next subobjective.

Stimulus similarity and dissimilarity in the sequencing of instruction relates to such procedures as introducing subject-matter content according to increasing similarity of form or meaning. Simple dissimilarities are introduced initially and, as these discriminations become learned, more difficult ones are introduced. In learning grapheme-phoneme correspondences, some programed instructional procedures [29] take account of this by introducing not all of the letters of the alphabet in early reading instruction, but only the maximally discriminable letters. More difficult letter discriminations are reserved until a sizable reading vocabulary has been built up with the initially learned letters.

Stimulus and response factors.—In addition to sequencing conditions, it is necessary in instruction to decide upon the ways in

27. Benton J. Underwood and Rudolph W. Schulz, *Meaningfulness and Verbal Learning*. New York: J. B. Lippincott Co., 1960.

28. Robert M. Gagné, "The Acquisition of Knowledge," *Psychological Review*, LXIX (July, 1962), 355-65.

29. Buchanan, *op. cit.*

which the student can perform and to determine how subject-matter material will be presented to him. This point has already been mentioned in considering the analysis of subject-matter content. The stimulus and response aspects of a subject-matter domain determine the dimensions along which a student can interact with it. In present-day instruction, since printed materials carry so much of the burden of instructional presentation, educators have scarcely begun to investigate new possibilities for providing interaction between the student and his subject matter, possibilities which are dictated by the stimulus and response characteristics of a subject matter. It seems possible to be able to present the learner with ways of seeing and manipulating his subject matter that extend and enrich his contact with it and to form a learning environment in which subject-matter dimensions need not be so drastically reduced as they may be when forced into a primarily paper-and-print learning environment. Engineering and engineering psychology have worked on the experimental analysis of the display and response characteristics by which a human can communicate with his environment. Similar concerns must be expressed in education with respect to the interface between student and subject matter. We need to examine the display and response characteristics by which a student can interact with a subject-matter discipline.[30] An example of this exciting trend is the development of graphical input and output facilities in automated instructional systems which can remove the student from the restrictions of keyboards and one-dimensional inputs. In computer-assisted instruction, a major innovation seems to be required in the form of input and output consoles which are possible with existing technology.

Practice.—Many of the early experiments in programed instruction involved the manipulation of the number of steps in a program so that programs with different numbers of frames, but teaching the same things, were compared. The results obtained from several studies along these lines are ambiguous.[31] However, they serve to make

30. Robert Glaser, William W. Ramage, and Joseph I. Lipson, *The Interface between Student and Subject Matter.* Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1964.

31. James G. Holland, "Research on Programing Variables," in *Teaching Machines and Programed Learning, II: Data and Directions, op. cit.*

one aware of how little is known that can be applied about the variable of practice, which is an old and respectable topic in learning. In designing programs, the amount of practice and review employed needs to be determined empirically and certainly is affected by individual differences. A pilot study by Hawker [32] shows that, after a program is completed, at least one-fifth of the frames can be removed without change in the average performance attained by a group.

A study completed by Reynolds and Glaser,[33] in which experimental sequences in junior high school general science were imbedded in a larger general science program, investigated the amount of repetition of stimulus and response in the learning of technical terms and also investigated the spacing of review sequences. The results, measured for immediate learning and retention, showed that variations in repetition had only transitory effects but that spaced review in the course of a programed instructional sequence significantly facilitated retention of the reviewed material. Similar results in a laboratory situation involving paired-associate learning with massed and distributed repetitions of items have been reported by Greeno.[34] The results suggest that the often-criticized monotony of repetition found in many early programed instructional materials may, in fact, be of little value in enhancing retention and may profitably be replaced by a series of short instructional sequences in several related topics, each interspersed with reviews of the preceding material. The general conclusion is that the entire question of practice, review, and retention with *meaningful* academic subject matter needs to receive more help from experimental psychology and requires extensive investigation in both laboratory and educational contexts.

Response contingencies—errors and correction.—The fact is that

32. Personal communication, 1964.

33. James H. Reynolds and Robert Glaser, "Effects of Repetition and Spaced Review upon Retention of a Complex Learning Task," *Journal of Educational Psychology*, LV (October, 1964), 297-308.

34. James G. Greeno, "Paired-Associate Learning with Massed and Distributed Repetitions of Items," *Journal of Experimental Psychology*, LXVII (March, 1964), 286-95.

practice, as such, does not change behavior but practice conditions which supply consequences of an individual's actions serve to modify his behavior. These response contingencies influence the course of learning. Because there are so many things that are not known, the study of the contingent relationships between behavior and consequent events is a key area for both basic and applied research in learning which is relevant to instruction. Although many studies have shown the powerful influence of various reinforcing operations,[35] Swets and his co-workers,[36] studying a task of categorizing the characteristics of different sounds, conclude that "fairly extensive feedback may be detrimental . . . and provide no support for the hypothesis that efficiency of learning varies directly with the probability of reinforcement." Such negative findings may be attributed to many sources and need to be analyzed carefully, particularly with respect to the nature of the terminal component repertoire and the sequencing between transitional and terminal behavior.

Response contingencies fall into several classes, reinforcing events being one class, and others being extinction, punishment, and correction. It is known, at least on a common-sense basis, that individuals learn from making errors, but very little is known about the process involved and how to use error behavior efficiently. Correction is highly relevant to instruction but has generally been neglected in psychological studies. Correction refers to the contingency whereby an incorrect response is followed by a stimulus event which serves to inform the student of the nature of the correct response in such ways as telling him the right answer, showing him how to get the right answer, making him perform the correct response, and so forth. How do students learn from their errors?

35. For example, Fred S. Keller and William N. Schoenfeld, *Principles of Psychology* (New York: Appleton-Century-Crofts, 1950); and C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (New York: Appleton-Century-Crofts, 1957).

36. J. A. Swets and Others, "Learning To Identify Nonverbal Sounds: An Application of a Computer as a Teaching Machine," *Journal of the Acoustical Society of America*, XXXIV (July, 1962), 928-35.

Some investigators, like Kaess and Zeaman,[37] after studying learning in multiple-choice situations with incorrect alternatives presented to the student, conclude that incorrect alternatives increase the probability that the student will repeat his error. Suppes and Ginsberg[38] report the desirability of overt correction procedures to facilitate learning in children. The research literature appears to suggest that there may be differences in the effects of correction between adults and children and also differences as a function of the behavior being learned. However, these are matters for investigation. The main point is that an important area for learning research relevant to instructional practice is the class of response contingencies called correction.

In recent studies, there have been provocative contrasts in the findings on the subject of learning with errors versus learning without error. Skinner's work with the teaching machine has emphasized the minimization of error. There has been some questioning of theories in which responding to an inappropriate stimulus (and hence the occurrence of errors) is a necessary condition for the formation of discriminations. The general rationale for error minimization in instruction seems to be the following: First, when errors occur, there is lack of control over the learning process, and opportunity is provided for the intermittent reinforcement of incorrect responses. This results in interference effects highly resistant to extinction. Second, frustration and emotional effects that are difficult to control are associated with extinction and interference from error. And third, richer learning, that is, richer in associations, takes place when the associative history of the learner is applied to extend his learning. This is accomplished by mediators or thematic prompting which make positive use of existing knowledge and serve to guide learning. Perhaps another reason behind the drive to minimize error is, as has been said, that the use of errors and the possible value of incorrect

37. W. Kaess and D. Zeaman, "Positive and Negative Knowledge of Results on a Pressey-Type Punchboard," *Journal of Experimental Psychology*, LX (July, 1960), 12-17.

38. Patrick Suppes and Rose Ginsberg, "Application of a Stimulus Sampling Model to Children's Concept Formation with and without Overt Correction Response," *Journal of Experimental Psychology*, LXIII (April, 1962), 330-36.

responses has been neither as widely nor as systematically investigated as other response contingencies.

Individuals concerned with more adaptive teaching procedures than the Skinner-type linear program make the case that errors must be used in the course of instruction.[39] Their procedures require that the student reveal, by making some sort of error, the kind of instruction he should receive next. If adaptive control is competently designed, student weaknesses are revealed by his selection of response alternatives. Where no adaptive procedures are available for dealing with error, the minimization of error is forced upon the teaching procedure. The advocates of error minimization recognize the presence of error but attempt to cue or prompt it out of existence in the course of designing a program for a particular population of students. Such nonadaptive programs attempt to remove error without allowing it to be manifested in overt mistakes. These programs of instruction, which attempt to forestall error, need to make provisions for far more error possibilities than any one student is likely to have, and probably wind up with less than an optimal series of challenging tasks. The summary point to be made is that an interesting area for learning research relevant to instructional practice is study of the response contingencies which follow the occurrence of incorrect responses.

Response contingencies—effective reinforcers.—Another general problem with respect to response contingencies is to determine the effective reinforcers in a subject-matter learning sequence. There is also the related practical problem of what reinforcing contingencies can be employed in designing instruction. As is known, reinforcement can be quite subtle. For example, Skinner points out that certain "consequences are used to motivate the beginning reader when a textbook is designed to be 'interesting.' Such reinforcement is not, however, contingent upon accuracy of response in the manner needed to shape skillful behavior."[40] The point is that an interest-

39. Brian N. Lewis and Gordon Pask, "The Theory and Practice of Adaptive Teaching Systems," in *Teaching Machines and Programed Learning, II: Data and Directions*, *op. cit.*

40. B. F. Skinner. *Verbal Behavior*, p. 66. New York: Appleton-Century-Crofts, 1957.

ing text may reinforce the behavior involved in obtaining meaning from printed material but may not differentially reinforce correct phonemic responses.[41] Reinforcing events must be determined on the basis of detailed analysis of appropriate subject matter and component repertoire relationships. Just as one identifies what stimuli feel hot or cold, pleasant or frightening, one needs to identify what events can serve as reinforcers for students in the course of learning certain subject matters.

Studies in learning and instruction do suggest the effectiveness of certain events as general reinforcing conditions. As an example, an apparently powerful reinforcer in learning is overt control of the physical environment. This has been suggested particularly by the work of Moore[42] on what he calls a responsive environment. This is related to the learning of subject-matter content, especially with respect to the study of behavior generally labeled as curiosity and exploration.[43] An increasing amount of research has been directed to the study of this area within the past decade.[44]

In infrahuman studies, research has been aimed at the discovery and identification of variables which serve to elicit and maintain curiosity and exploratory behavior in the absence of conventional laboratory motives, such as hunger or thirst or other conditions of deprivation. The specific responses which have been observed are such behaviors as orienting, approaching, investigating, and manipulating. The significant variables influencing such exploratory responses have been characterized as stimulus objects or patterns that are novel, unfamiliar, complex, surprising, incongruous, asymetrical, and so forth. All these aspects generally can be described as a change in the stimulus displayed to the individual. Research has

41. Silberman, *op. cit.*

42. Omar K. Moore, "Autotelic Responsive Environments and Exceptional Children," in *The Special Child in Century 21*. Seattle, Washington: Special Child Publications, 1964.

43. These comments on curiosity and exploratory behavior were significantly influenced by the work of the author's colleague, Professor Harry Fowler, at the University of Pittsburgh.

44. Harry Fowler, *Curiosity and Exploratory Behavior* (New York: Macmillan Co., 1965); and D. E. Berlyne, *Conflict, Arousal, and Curiosity* (New York: McGraw-Hill Book Co., 1960).

indicated that the strength of exploratory behavior that is elicited is positively related, within limits, to the degree of change in the stimulus situations introduced into the environment. Too great or too abrupt a change, however, is disrupting and may preclude exploration.

In complex situations, an individual encounters change by way of his interaction with or manipulation of the elements of a stimulus pattern. Such interaction provides the stimulus change which can elicit curiosity and exploratory behavior. Investigations have demonstrated that behaviors are learned when they lead to a change in the stimulus display. Thus, in addition to stimulus change eliciting exploratory behavior, experiments show that organisms will respond in order to secure novel, unfamiliar stimuli. In general, these findings demonstrate that stimulus change or sensory variation may be employed to selectively reinforce behaviors which result in stimulus change, and that this variation in the stimulus situation will serve concomitantly to elicit exploratory behavior. When stimulus change is used as a reinforcing stimulus, it seems reasonable to hypothesize that learning variables which influence acquisition and extinction will influence the acquisition and extinction of exploratory behavior and curiosity as they do other learned behavior. This suggests that a student's curiosity and explorations may be both elicited and selectively maintained in an instructional environment which provides for appropriate variation and change in both the stimulus characteristics of the subject materials confronting the student and the responses he must make to these materials.

Measuring Learning Outcomes

An effective technology of instruction relies heavily upon the effective measurement of subject-matter competence at the beginning, in the course of, and at the end of the educational process. The mastery of the skills and knowledges required to begin an instructional sequence and to continue along its course insures the availability of behavior which the teacher and the student can rely on for use in subsequent learning. Elsewhere the author [45] has

45. Robert Glaser, "Instructional Technology and the Measurement of Learning Outcomes: Some Questions," *American Psychologist*, XVII (August, 1963), 519-21.

pointed out that recent work in instructional design, such as programed instruction, has raised into prominence a number of questions concerning the nature of measures of student achievement and the assessment of subject-matter competence (as it may be defined by recognized subject-matter scholars). Achievement measurement can be defined as the assessment of criterion behavior involving the determination of the characteristics of student performance with respect to specified standards. Achievement measurement is distinguished from aptitude measurement in that the instruments used to assess achievement are specifically concerned with the properties of present performance, with emphasis on the meaningfulness of its content. By contrast, aptitude measures derive their meaning from a demonstrated relationship between present performance and the future attainment of specified knowledge and skill. In certain circumstances, of course, this contrast is not quite so clear—for example, when achievement measures are used as predictor variables.

The scores obtained from an achievement test can provide primarily two kinds of information. One is the degree to which the student has attained criterion performance—for example, whether he can satisfactorily prepare an experimental report or solve certain kinds of word problems in arithmetic. The second type of information that an achievement test score provides is the relative ordering of individuals with respect to their test performance—for example, whether Student A can solve his problems more quickly than Student B. The principal difference between these two kinds of information lies in the standard used as a reference. The standard against which a student's performance is compared in order to obtain the first kind of information is the criterion behavior which defines increasing subject-matter competence along a continuum of achievement. Criterion levels of competence can be established at any point in instruction where it is necessary to obtain information as to the adequacy of a student's performance. Behaviorally defined objectives describe the specific tasks a student must be capable of performing in order to achieve a particular knowledge or competence level. The student's score with respect to these tasks provides explicit information as to what he can or cannot do and indicates the correspondence between what the student does and the achievement criteria at that point in his learning. Measures cast in terms of such

criterion standards provide information as to the degree of competence obtained by a particular student which is independent of reference to the performance of others.

On the other hand, achievement measures also convey information about the capability of a student compared with the capability of other students. In instances where a student's relative standing is the primary purpose of measurement, reference need not be made to criterion behavior. Educational achievement examinations, for example, are administered frequently for the purpose of determining the comparative standing of students in a class or school rather than for assessing their attainment of specified curriculum objectives. When such norm-referenced measures are used, a particular student's achievement is evaluated in terms of a comparison between his performance and the performance of other members of the group. Such measures need provide little or no information about the degree of proficiency actually exhibited by the individual. They tell that one student is more or less proficient than another but do not tell how proficient either of them is with respect to the subject-matter tasks involved. In large part, achievement measures currently employed in education are norm referenced, and work needs to be done which will contribute to the development of criterion-referenced tests in order to assess the outcomes of learning. Criterion-referenced measures can provide information about both degree of competence and relative standing.

A further point along these lines relates to the fact that achievement tests are used not only to provide information about the student but also to provide information about the effects of different teaching procedures and instructional designs. It seems likely that tests which are constructed to be sensitive to individual student differences may not be the same kinds of tests that are sensitive to the differences produced by different instructional conditions. Test theory, for the most part, has been concerned primarily with the development of tests that are maximally sensitive to individual differences. Less work has been concerned with test development for the purpose of curriculum evaluation and curriculum design. This point is further discussed in the article referred to above [46] and

46. *Ibid.*

more fully in an article by Cronbach[47] concerned with course improvement through evaluation. Cronbach writes, "I am becoming convinced that some techniques and habits of thought of the evaluation specialist are ill-suited to current curriculum studies. . . . how must we depart from the familiar doctrines and rituals of the testing game?" (p. 672) and, "The three purposes—course improvement, decisions about individuals, and administrative regulation—call for measurement procedures having somewhat different qualities" (p. 677).

Conclusion

This chapter has attempted to give some of the research approach and perspective that is likely to be introduced into the design of instructional procedures in the future, as behavioral science and educational practice begin to be related in a mutually helpful way. It is fair to say that at the present time the influence of modern experimental psychology is rarely significant in the development of instructional materials and teaching procedures. It is hypothesized that, in the future, four main areas of the educational process will be influenced: (*a*) Instructional goals will be analyzed in terms of both subject-matter content and categories of student behavior that suggest strategies of teaching. (*b*) The diagnosis of the learner's strengths and weaknesses prior to instruction for appropriate pedagogical guidance will become a more definitive process so that it can aid in the design of a curriculum specially suited for the student involved. (*c*) The techniques and materials employed by the teacher will undergo significant change. (*d*) The ways in which the outcomes of education are assessed, both for student evaluation and curriculum improvement, will receive more attention.

As these changes occur, it is likely that they will result in certain changes in school operation. First, the role of the teacher will be restructured. It seems likely that the teacher will be able to become more concerned with individual student guidance and individual progress than he is likely to be at present in his role as group mentor.

47. Cronbach, *op. cit.*

Second, the educators' goal of the individualization of student progress based upon student background, aptitude, and achievement will come closer to realization through school reorganization and the adoption of new practices. Third, instructional materials and devices supplied by industry will come under close scrutiny as to their instructional effectiveness (just as tests came under close scrutiny with respect to reports on their reliability and validity). Fourth, subject-matter competence will be easier to attain for a larger number of pupils in our schools, and tests which measure progress toward mastery will become important aids for the quality control of educational excellence. These developments, necessarily based on a developing body of pedagogical principles, should advance teaching toward the status of a profession nurtured by underlying behavioral sciences which are becoming increasingly relevant to the educational process.